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Zhang, Chao ; Bucher, Hugo ; Shen, Shu-Zhong

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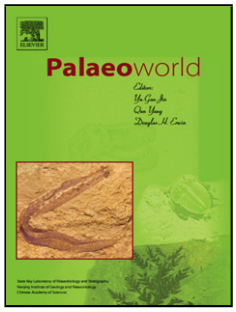

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Griesbachian and Dienerian (Early Triassic) ammonoids from Qubu in the Mt. Everest area, southern Tibet

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Abstract

The Permian–Triassic boundary (PTB) is defined by the conodont *Hindeodus parvus* at Meishan section D in the palaeotropical Tethyan region, where basal Triassic ammonoids are rare and poorly preserved. Here we describe some basal Early Triassic ammonoids from the lower part of the Kangshare Formation at the Qubu section in the Mt. Everest area in southern Tibet, China. Our study recognizes three distinct ammonoid zones, the *Otoceras woodwardi*, *Ophiceras tibeticum*, and *Ambites* zones in ascending order. The occurrence of *Otoceras*, a key basal Triassic taxon, is here documented for the first time in this area. The first occurrence of Triassic conodonts at Qubu indicates that the PTB is not higher than the level 0.81 m above the base of the dolomite unit of the Kangshare Formation, and the first occurrence of the ammonoid *Otoceras woodwardi* is 0.89 m higher up at the section. At Qubu, the Griesbachian–Dienerian boundary is placed between the *Ophiceras tibeticum* Zone and the *Ambites* Zone. Our work represents a valuable addition for the construction of a high resolution of Griesbachian and Dienerian ammonoid biozonations in southern Tibet and provides a framework for the basal Triassic correlation in the Mt. Everest area.

Keywords: ammonoids; Early Triassic; Permian–Triassic boundary; Qubu; *Otoceras*

1. Introduction

Otoceras is a widely distributed ammonoid genus in both the peri-Gondwanan region and the Boreal Realm (e.g., Griesbach, 1880; Kummel, 1972), and its first occurrence was traditionally considered to be the base of the Triassic (e.g., Griesbach, 1880; Jenks et al., 2015). However, the current PTB was defined by the First Appearence Datum (FAD) of the conodont *Hindeodus parvus* at Meishan section D in the palaeotropical Tethyan region (Yin et al., 2001), a definition with shortcomings

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(e.g., Brosse et al., 2016). The record of basal Triassic ammonoids in Meishan is poor and extremely discontinuous in comparison with the records from the peri-Gondwanan region and the Boreal Realm. Thus, the PTB sections in the peri-Gondwanan region become very important because some of them contain both well preserved ammonoids and abundant conodonts, and provide a direct correlation between the conodont and ammonoid successions in the basal Triassic. Moreover, the PTB sections in the peri-Gondwanan region also provide a record of the end-Permian mass extinction pattern in the relatively high-latitude area in the southern hemisphere (Shen et al., 2006). The scarcity of marine rocks of the Permian–Triassic transition relates to the presence of a global low sea-level stand straddling the PTB (e.g., Baresel et al., 2017) combined with a globally reduced production of neritic carbonate required for ammonoid preservation. The amplitude of the gap may be further increased by the lack of accommodation space resulting from regional tectonics, as commonly observed in the peri-Gondwanan region. There, the Griesbachian ammonoid record is at best represented by a few fossiliferous beds that are affected either by condensation, substantial hiatuses (e.g., Spiti; Ghosh et al., 2015) and/or by dolomitization (e.g., the Salt Range; Kummel and Teichert, 1970; Tulong in southern Tibet; Rao and Zhang, 1985). Therefore, every new piece of information may potentially add to the available record.

Early Triassic ammonoids from southern Tibet, which is also a part of the peri-Gondwanan region, were first reported at Selong and Tulong by Wang and He (1976). In southern Tibet, the classic Himalayan *Otoceras woodwardi* Zone at the base of the Early Triassic (Mojsisovics et al., 1895) is only known from Selong, where it has been documented at above the *Otoceras latilobatum* Zone, a zone established by Wang et al. (1989). In Tulong, we noted that the dolomitic limestone at the base of Triassic was strikingly similar to the lower unit of the Kathwai Member in the Salt Range, Pakistan (Brühwiler et al., 2009). The dolomitic limestone at Tulong yields abundant conodonts and some ammonoids (Rao and Zhang, 1985). This dolomitic limestone is overlain by a thin limestone unit yielding ammonoids of Dienerian age, but no identifiable Griesbachian ammonoids could be recovered by

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Brühwiler et al. (2009). The same lithological succession is here documented from Qubu in the Mt. Everest area in southern Tibet (Fig. 1), but the less intense dolomitization allows recovering a succession comprising identifiable Griesbachian ammonoids in addition to those of Dienerian age. Biostratigraphical correlations are proposed with Selong and Tulong in southern Tibet and other localities in the peri-Gondwanan region.

2. Geological setting and stratigraphy

The Qubu area is near the China–Nepal border, 30 km north of Mt. Everest (Fig. 1b). A sequence of two Permian formations is distinguished with the Qubu Formation in the lower and the Qubuerga Formation in the upper at the Qubu section. The Qubu Formation is composed mainly of coarse white quartzose sandstone and so far, no marine fossils have been reported from this formation. Hsu (1976) reported a *Glossopteris* flora from a shale unit in this formation and assigned it to a Wuchiapingian age. The Qubuerga Formation can be divided into two main parts. The lower part is composed mainly of bioclastic limestone interbedded with calcareous fine-grainded sandstone. Very abundant brachiopods have been studied in detail and were assigned a Lopingian age (Shen et al., 2003). Some rare ammonoid specimens were reported from this part, too. They were first identified as *Uraloceras xizangensis* and an Artinskian age for the Qubuerga Formation was assigned by Liang in Ching et al. (1977). These were re-assgined to *Roadoceras xizangensis* based on more recently collected materials and a possible Lopingian age was suggested (Shen et al., 2004).

The Permian–Triassic transition at the Qubu section is marked by a distinct reddish dolomite unit in the basal part of the Kangshare Formation. This unit is underlain by a varicoloured shale unit (Unit 2 of this paper), which belongs to the Lopingian Qubuerga Formation (Shen et al., 2003; Pan and Shen, 2008). It is generally comparable with the Kuling Shale in Spiti, India (Garzanti et al., 1996; Ghosh et al., 2015) or the Nimaluoshenza Member at Tulong in southern Tibet (Rao and Zhang, 1985). This member contains latest Permian gastropods dominated by a *Bellerophon* fauna (Pan and Shen, 2008) and some poorly-preserved *Xenodiscus*-like

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ammonoids in the shales.

The dolomite unit of the Kangshare (or Tulong) Formation at the Qubu section is about 2.5 m thick (Fig. 1a). Such a dolomite unit is widely distributed in the peri-Gondwanan region including Tulong in southern Tibet (Rao and Zhang, 1985; Brühwiler et al., 2009); the Salt Range, Pakistan (Kummel and Teichert, 1970; Pakistan-Japanese Research Group, 1985; Ware et al., in press) and some places in Spiti, India (Kummel and Teichert, 1970; Garzanti et al., 1996; Waterhouse, 2010; Ghosh et al., 2015). Both the latest Changhsingian and the earliest Triassic conodonts including *Hindeodus parvus* have been reported from this unit (Fig. 2b; Shen et al., 2006).

Our ammonoid materials were collected from two nearby localities at Qubu, the classic Qubu section (called the QB section, Fig. 2a, b) and a new section 300 m further south (called the QB2 section, Fig. 2a). The lowest part of the Kangshare Formation at the QB section (Unit 1 in this paper) can be further subdivided into two parts: the lower one (Subunit a) consists of red dolomitic limestone and thin shales and the upper one (Subunit b) is composed of gray limestone and shales. The lithology of the QB2 section is almost the same as the QB section except for fewer shales in the lowest Kangshare Formation.

3. Ammonoid succession

As shown in Fig. 2b, four beds yield identifiable ammonoids in the QB section. QB-13 contains *Otoceras woodwardi* and *Ophiceras* sp., QB-15 contains *Ophiceras tibeticum*, *O. demissum*, and *Discophiceras wordiei*, QB-16 contains *Ophiceras tibeticum*, and QB-18 yields *Ambites* sp. and *Ussuridiscus*? sp. Three zones, namely the *Otoceras woodwardi*, *Ophiceras tibeticum*, and *Ambites* zones can be recognized (Fig. 7).

The widely-distributed *Otoceras woodwardi* Zone is thought to represent the basal Triassic in the Himalayas (e.g., Shigeta and Zakharov, 2009; Balini et al., 2010). The QB section shows that the first occurrence of the ammonoid *Otoceras woodwardi* is slightly higher than the first occurrence of the conodont *Hindeodus parvus*, which is

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about 0.81 m above the base of the dolomite unit of the Kangshare Formation (Shen et al., 2006) (Fig. 2). Hence, it is clear that the PTB at Qubu is not higher than 0.81 m above the base of the dolomite unit and that Bed QB-13 is well within the Griesbachian.

According to Ware et al. (2015), *Ambites* is a characteristic middle Dienerian genus. Therefore, Bed QB-18, QB2-8, and QB2-11 are assigned a middle Dienerian age. Thus, the Griesbachian–Dienerian boundary is somewhere between Bed QB-16 and QB-18 in the QB section.

No late Griesbachian and early Dienerian ammonoids were recovered from the 15 cm-thick shaly interval between Bed QB-16 and QB-18. The absence of late Griesbachian and early Dienerian strata suggests a probable selective preservation problem due to the lack of carbonate in the interval and/or a gap.

4. Correlation with other peri-Gondwanan localities

The Permian–Triassic transitional lithological succession of the Tulong section is almost the same as that of Qubu, with varicolored shales in the top part of the Permian (Changhsingian), followed by dolomitic limestone (Permian–Triassic transition) and limestone (Early Triassic) in the upper part. In Tulong, dolomitization of the middle part is more intense than in Qubu. The only known ammnoids from that part were published by Wang and He (1976) and Rao and Zhang (1985). These authors also listed Dienerian and Smithian species from the same beds, which may be resulted from sampling biases. The upper part (Subunit b) of the Qubu section is slightly different from that of the Tulong section, where a Griesbachian/Dienerian transitional ammonoid assemblage dominated by *Prionolobus* and *Gyronites* in the upper part of Unit 1b is present (Brühwiler et al., 2009).

In constrast to Qubu and Tulong, the latest Permian at Selong consists of fossil-rich bioclastic limestone (Jin et al., 1996; Shen and Jin, 1999). The lower Triassic part, which is also dolomitic and yields *Otoceras* (Wang and He, 1976), is defined as *Otoceras latilobatum* Zone (Wang et al., 1989). However, the difference between the *Otoceras latilobatum* and *O. woodwardi* resides only in the lack of a

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flared umbilical margin, which is probably due to poor preservation. *Otoceras latilobatum* is thus a likely synonym of *O. woodwardi* and the *Otoceras latilobatum* Zone of Wang et al. (1989) cannot be distinguished from the *Otoceras woodwardi* Zone. The late Griesbachian part at Selong is also characterized by the presence of *Ophiceras tibeticum*, which is also documented at Qubu. The Dienerian part at Selong contains *Gyronites*, but lacks *Ambites* (Wang et al., 1989), which is different from that interval at Qubu.

The lithology of the Kathwai Member in the lower part of the Early Triassic Mianwali Formation in the Salt Range, Pakistan, is strikingly similar to the dolomitic unit at Qubu (Kummel and Teichert, 1970; Pakistan-Japanese Research Group, 1985; Shen et al., 2003). It is characterized by the presence of *Ophiceras connectens* (Pakistan-Japanese Research Group, 1985), which was treated as a synonym of *O. tibeticum* by Waterhouse (1994) who considered this bed as an equivalent of the *O. tibeticum* Zone. Although acceptance of this equivalence needs a full revision of the *Ophiceras* group, we assume for the time being that the *Ophiceras connectens* Zone is an equvialent of the *Ophiceras tibeticum* Zone at Qubu. Above the Kathwai Member is the Ceratite Limestone, which yields abundant *Ambites* in the lower part. It is equivalent to the *Ambites* Zone at Qubu.

In Spiti, the condensed basal Triassic constists mostly of limestone yielding *Otoceras woodwardi* and *Ophiceras tibeticum* (Krystyn et al., 2004, 2007), which are probably equivalent to Bed QB-13 and QB-15, 16 at Qubu respectively. The Dienerian there is composed mostly of shales with some thin limestone beds. Its lower part yields *Gyronites* and the middle part contains *Ambites* (Ware et al., 2015). The *Ambites* Zone at Qubu is thus a likely equivalent of the middle part of the shale unit in Spiti.

5. Systematic paleontology

Descriptions mainly follow the procedure given by Korn (2010). All specimens described here are housed in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences (prefixed “NIGP”).

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Order Ceratitida Hyatt, 1884

Family Otoceratidae Hyatt, 1900

Genus *Otoceras* Griesbach, 1880

Type species: *Otoceras woodwardi* Griesbach, 1880 from the Lower Triassic of the Himalayas, India.

Diagnosis: Shell involute, with very deep umbilicus and rapidly increasing outer whorls. Ombilical margin flared and venter tricarinate, thus imparting the section a more or less rhomboidal aspect (Spath, 1934).

Kummel (1972) re-assigned all the previously published species of *Otoceras* to a single species (*Otoceras woodwardi*) and two subspecies (*O. woodwardi woodwardi* and *O. woodwardi boreale*). He considered *Otoceras concavum* as being a variant of *Otoceras woodwardi boreale*. However, Bando (1981) referred to the distinct whorl shape of *Otoceras concavum* and kept it as a valid species.

Otoceras woodwardi Griesbach, 1880

(Fig. 3A, B)

1880 *Otoceras woodwardi* – Griesbach, p. 106, pl. 1, figs. 4, 5; pl. 2, figs. 1-6.

1880 *Otoceras woodwardi* var. *undatum* – Griesbach, p. 107, pl. 1, fig. 5.

1897 *Hungarites* (*Otoceras*) *fissisellatum* – Diener, p. 163, pl. 3, fig. 3; pl. 5, fig. 6; pl. 6, fig. 15.

1897 *Hungarites* (*Otoceras*) *parbati* – Diener, p. 160, pl. 4, fig. 1.

1897 *Hungarites* (*Otoceras*) *undatum* Griesbach – Diener, p. 162, pl. 4, fig. 6.

1897 *Hungarites* (*Otoceras*) *woodwardi* Griesbach – Diener, p. 156, pl. 2, fig. 1; pl. 3, fig. 1; pl. 4, figs. 2-5; pl. 5, figs. 1, 3, 5; pl. 6, fig. 16.

1897 *Hungarites* sp. – Diener, p. 150, pl. 23, fig. 5.

1897 *Otoceras clivei* – Diener, p. 161, pl. 3, figs. 2, 4; pl. 5, fig. 4; pl. 7, fig. 17.

1901 *Otoceras woodwardi* Griesbach – Frech, p. 575, text-fig. 4a-d.

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1902 *Otoceras woodwardi* Griesbach – Frech, p. 628.

1909 *Otoceras clivei* Diener – Krafft and Diener, p. 116.

1909 *Otoceras woodwardi* Griesbach – Krafft and Diener, p. 116.

1909 *Otoceras* cf. *undatum* Griesbach – Krafft and Diener, p. 116.

1915 *Otoceras clivei* – Diener, p. 213.

1915 *Otoceras draupadi* – Diener, p. 213.

1915 *Otoceras fissisellatum* – Diener, p. 213.

1915 *Otoceras parbati* – Diener, p. 213.

1915 *Otoceras undatum* Griesbach – Diener, p. 213.

1915 *Otoceras woodwardi* Griesbach – Diener, p. 213.

1925 *Otoceras woodwardi* Griesbach – Diener, p. 34, pl. 22, fig. 1.

1930 *Otoceras woodwardi* Griesbach – Spath, p. 9.

1930 *Otoceras* (*Metotoceras*) *dieneri* – Spath, p. 8.

1934 *Otoceras fissisellatum* Diener – Spath, p. 68.

1934 *Otoceras undatum* Griesbach – Spath, p. 69.

1934 *Otoceras woodwardi* Griesbach – Spath, p. 66, text-fig. 10.

1934 *Otoceras* (*Metotoceras*) *dieneri* – Spath, p. 69.

1935 *Otoceras boreale* – Spath, p. 9, pl. 1, figs. 1a, 1b, 6; pl. 2, figs. 2, 3; pl. 3, figs. 1-3; pl. 4, fig. 1; pl. 5, fig. 1; pl. 6, fig. 1.

1935 *Otoceras woodwardi* Griesbach – Spath, p. 11.

1957 *Otoceras boreale* Spath – Arkell et al., p. 1501.

1957 *Otoceras woodwardi* Griesbach – Arkell et al., p. L132, text-fig. 162(10).

1957 *Otoceras* (*Metotoceras*) *dieneri* Spath – Arkell et al., p. L132.

1961 *Otoceras boreale* Spath – Keller et al., p. 187.

1961 *Otoceras boreale* Spath – Tozer, p. 45, pl. 6, figs. 1-3; pl. 7, figs. 1-3; pl. 8, figs. 1-4; text-fig. 7.

1967 *Otoceras boreale* Spath – Tozer, pl. 2, figs. 1, 2.

1968 *Otoceras boreale* Spath – Tozer and Parker, pl. 27, figs. b-d.

1969 *Otoceras boreale* Spath – Trümpy, p. 83.

1970 *Otoceras clivei* Diener – Nakazawa et al., pl. 28, fig. 1a-c.

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1970 *Otoceras draupadi* Diener – Nakazawa et al., pl. 28, fig. 3a, b.

1971 *Otoceras boreale* Spath – Zakharov, p. 50, pl. 5, figs. 1-10.

1972 *Otoceras woodwardi* Griesbach – Kummel, p. 391, pl. 1, figs. 1-12.

1972 *Otoceras woodwardi boreale* Griesbach – Kummel, p. 391.

1976 *Otoceras latilobatum* Wang – Wang and He, p. 267, pl. 4, figs. 6, 7.

1981 *Otoceras woodwardi* Griesbach – Bando, p. 141, pl. 14, figs. 1-3; pl. 16, fig. 6; pl. 18, fig. 3.

1985 *Otoceras woodwardi* Griesbach – Waterhouse and Gupta, p. 220, pl. 1, figs. 3, 4; text-figs. 1, 2.

1989 *Otoceras latilobatum* Wang – Wang et al., pl. 1, fig. 18.

1989 *Otoceras woodwardi* Griesbach – Wang et al., pl. 1, fig. 21.

1994 *Otoceras boreale* Spath – Tozer, p. 55, pl. 1, fig. 1a, b; pl. 2, figs. 1, 8; p. 350, text-fig. 4a-f; p. 352, text-fig. 5a.

1994 *Otoceras gracile* – Tozer, p. 54, pl. 1, fig. 2a, b; p. 350, text-fig. 4g.

1994 *Otoceras woodwardi* Griesbach – Waterhouse, p. 38, pl. 1, figs. 6-12; pl. 2, figs. 1-3; pl. 3, figs. 2, 3; text-figs. 6B, 8.

1996 *Otoceras boreale* Spath – Dagys and Ermakov, p. 404, pl. 3, fig. 2; pl. 4, fig. 1; pl. 6, fig. 1; text-fig. 3c.

Material and occurrence: Two specimens (NIGP 16320-16321) are registered. Both are from Bed QB-13 at the QB section.

Description: Shell moderatly involute and moderately compressed, somewhat discoidal in outline. Venter tricarinate with three distinct keels. Umbilicus deep, rimmed by a flared umbilical margin. Suture line unknown.

Measurements: See Table 1.

Discussion: The specimens are poorly preserved, but the strongly flared umbilical margin and the shape of the whorl section show the diagnostic characters of *Otoceras woodwardi*. *Otoceras latilobatum* differs from *O. woodwardi* by lacking a flared umbilical margin, which is a questionable distinction because of the poor preservation of the type material of *O. latilobatum*. Here we consider *O. latilobatum* as a synonym

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of *O. woodwardi*.

Family Ophiceratidae Arthaber, 1911

Genus *Ophiceras* Griesbach, 1880

Type species: *Ophiceras tibeticum* Griesbach, 1880 from the Lower Triassic of the Himalayas, India.

Diagnosis: Compressed, evolute Ophiceratidae with rounded venter, elliptical whorl-section, and generally high umbilical wall. Smooth, and with sigmoidal growth striae, which sometimes coalesce to form ribs; suture lines simple and ceratitic.

Diener (1897) distinguished two groups and 10 species among the Himalayan forms assigned to *Ophiceras*. The first group is that of *Ophiceras tibeticum* Griesbach, which includes *Ophiceras tibeticum* Griesbach, *O. gibbosum* Griesbach, *O. serpentium* Diener, and *O. playspira* Diener. The second group is that of *Ophiceras sakuntala* Diener, which includes *O. sakuntala* Diener, *O. medium* Griesbach, *O. ptychodes* Diener, *O. demissum* Oppel, *O. chamunda* Diener, and *O. dharma* Diener. Krafft and Diener (1909) removed *Ophiceras dharma* and added *O. stricturatum*. The group of *Ophiceras tibeticum* Griesbach is distingished by “strong falciform folds and knob-like elevations”, whereas the other group is “perfectly smooth or covered with low and broad falciform folds” (Kummel, 1972).

Kummel (1972) noticed that this classificaton was largely typological, with many transition forms. He suggested grouping them in the three following species: *Ophiceras tibeticum*, *O. serpentium*, and *O. medium*.

Because our own material is very limited, intraspecific variation cannot be assessed and the species definitions of various *Ophiceras* cannot be improved. Therefore, we follow the main lines of Diener’s classification.

Ophiceras tibeticum Griesbach, 1880

(Figs. 3E, 4A, 4B)

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1880 *Ophiceras tibeticum* – Griesbach, p. 109, pl. 3, figs. 1-7.

1897 *Ophiceras serpentinum* – Diener, p. 110, pl. 13, figs. 1-7.

1897 *Ophiceras tibeticum* Griesbach – Diener, p. 105, pl. 8, figs. 1-7.

1909 *Ophiceras tibeticum* Griesbach – Kraff and Diener, p. 81.

1909 *Ophiceras* cf. *serpentinum* Diener – Krafft and Diener, p. 82.

1913 *Ophiceras* cf. *tibeticum* Griesbach – Diener, p. 18, pl. 1, fig. 4.

1915 *Ophiceras serpentinum* – Diener, p. 212.

1934 *Ophiceras serpentinum* Diener – Spath, p. 74.

1934 *Ophiceras tibeticum* Griesbach – Spath, p. 73, text-fig. 13d, e.

1957 *Ophiceras tibeticum* Griesbach – Arkell et al., p. L132, text-fig. 165(5).

1972 *Ophiceras serpentium* Diener – Kummel, p. 384, pl. 6, figs. 1-12.

1972 *Ophiceras tibeticum* Griesbach – Kummel, p. 384, pl. 5, figs. 1-10; pl. 9, fig. 15.

1976 *Ophiceras tibeticum* Griesbach – Wang and He, p. 269, pl. 6, figs. 6-8; text-fig. 6a.

1979 *Ophiceras tibeticum* Griesbach – Wang et al., p. 106, pl. 1, figs. 1, 2.

?1981 *Ophiceras serpentinum* Diener – Bando, p. 145, pl. 16, fig. 10.

1981 *Ophiceras tibeticum* Griesbach – Bando, p. 144, pl. 15, fig. 1.

1989 *Ophiceras tibeticum* Griesbach – Wang et al., pl. 1, fig. 19.

Material and occurrence: 3 specimens (NIGP 16322-16324) are registered. NIGP 16322-16323 are from Bed QB-15, and NIGP 16324 is from Bed QB-16 at the QB section.

Description: Small to moderate size, evolute. Flanks slowly converge towards the rounded venter. Whorl section subtrapezoidal, with maximal thickness at umbilical magin. Umbilicus shallow and broad, umbilical wall steep, umbilical margin rounded but distinct. Surface smooth. Suture line ceratitic, with proportions in agreement with that of *Ophiceras*.

Measurements: See Table 1.

Discussion: *Ophiceras tibeticum* is thought to have narrow folds or wrinkles (e.g.,

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Diener, 1897), and only the specimen NIGP 16324 has faint folds. Although our specimens are relatively smooth (perhaps because of poor preservation), they have the characteristic umbilical margins and walls of *Ophiceras tibeticum*.

Ophiceras demissum Oppel, 1865

(Fig. 4C)

1865 *Ammonoites demissus* – Oppel, p. 290, pl. 86, fig. 1a-c.

1897 *Ophiceras demissum* Oppel – Diener, p. 121, pl. 14, figs. 1-7.

1909 *Ophiceras* cf. *demissum* Oppel – Kraft and Diener, p. 82.

1913 *Ophiceras demissum* Oppel – Diener, p. 17, pl. 1, figs. 8, 9.

1934 *Ophiceras demissum* Oppel – Spath, p. 74.

1937 *Ophiceras demissum* Oppel – Hsu, p. 378, pl. 1, fig. 1.

1972 *Ophiceras medium* Griesbach – Kummel, p. 384, pl. 9, figs. 9-14.

1976 *Ophiceras demissum* Oppel – Wang and He, p. 271, pl. 2, figs. 1-3, 7-9; text-fig. 6b-d.

1979 *Ophiceras demissum* Oppel – Wang et al., p. 107, pl. 1, figs. 9-11.

Material and occurrence: 1 specimen (NIGP 16325) is registered, from Bed QB-15 at the QB setion.

Description: Moderate size, evolute. Flanks slightly convex, with maximal thickness at the inner middle part of the flanks. Whorl section oval. Venter broadly rounded. Umbilicus shallow and wide. Umbilical margin broadly rounded and indistinct. Surface smooth. Suture line unknown.

Measurements: See Table 1.

Discussion: Our specimen is identified as *Ophiceras demissum* based mainly on its characteristic oval whorl shape.

Ophiceras sp.

(Fig. 3C, D)

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Material and occurrence: 2 specimens (NIGP 16326-16327) are registered from Bed QB-13 at the QB section.

Description: Moderate size, evolute. Venter rounded. Umbilicus shallow and wide. Surface seem to be smooth. Suture line unknown.

Measurements: See Table 1.

Disscussion: The poor preservation of the present specimens results in a loss of valuable information for identification, including the lack of suture lines. However, the general outline of the shells is in agreement with that of *Ophiceras*.

Genus *Discophiceras* Spath, 1935

Type species: *Ophiceras* (*Lytophiceras*) *subkyokticum* Spath, 1930 from the Lower Triassic, *Ophiceras wordiei* beds, East Greenland.

Diagnosis: Close to *Ophiceras*, but with tendency to flat, discoidal, shape and high whorl-sides, small, often excentric umbilicus and narrowing or sharpening of the periphery. Suture-line as in *Ophiceras* (*Lytophiceras*) *commune* of *O.* (*L.*) *sakuntala*, in most species (Spath, 1935).

Discophiceras wordiei Spath, 1930

(Fig. 4D)

1930 *Ophiceras* (*Lytophiceras*) *wordiei* – Spath, p. 26, pl. 5, figs. 1a, 1b, 2a, 2b, 9a, 9b; pl. 6, figs. 1a, 1b, 2a, 2b.

1935 *Ophiceras* (*Discophiceras*) *wordiei* Spath – Spath, p. 32, pl. 7, fig. 7a, b; pl. 8, fig. 5a, b; pl. 16, fig. 8a, b; text-fig. 1h.

1967 *Discophiceras wordiei* Spath – Tozer, p. 16.

1994 *Discophiceras wordiei* Spath – Tozer, p. 57, pl. 2, fig. 9a, b; p. 352, text-fig. 5f.

Material and occurrence: 1 specimen (NIGP 16328) is registered from Bed QB-15

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at the QB setion.

Description: Shell small, moderately involute. Flanks converge toward the periphery with a distinct curvature, forming a narrowly rounded venter. Umbilicus shallow, umbilical wall steeply inclined, umbilical margin rounded. Surface smooth. Suture line poorly preserved, but clearly ceratitic.

Measurements: See Table 1.

Disscussion: Our specimen is slightly more involute than the holotype. The umbilical wall of our speicmen is slightly steeper.

Family Gyronidae Waggen, 1895

Genus *Ambites* Waagen, 1895

Type species: *Ambites discus* Waagen, 1895 from Ceratite Marls in the Salt Range, Pakistan.

Diagnosis: Compressed, moderately involute, platyconic to serpenticonic Gyronitidae with a tabulate venter. Ventro-lateral shoulders protruding over the flanks, usually underlined by a very thin strigation and by a slight concavity on the flanks, giving the ventral part of the whorl section a bottlenecked outline. Ornamentation varying from nearly smooth forms to variants bearing two spiral ridges and sigmoid ribs or folds on flanks. Suture line simple, lobes with numerous small identations, auxiliary series of variable length, with small indentations and generally no differentiated auxiliary lobe.

Ambites sp.

(Fig. 5A-C)

Material and occurrence: 3 specimens (NIGP 16329-16331) are registered. NIGP 16329 is from Bed QB-18 at the QB section. NIGP 16330 is from Bed QB2-8 at the QB2 section. NIGP 16331 is from a float block at the QB section.

Description: Shell moderately involute, compressed and platyconic. Flanks slightly convex, with maximal thickness in the middle part. “Bottleneck” ventral shoulders.

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Venter tabulate. Umbilicus shallow with a rounded margin. Surface smooth. Suture line simple and weakly ceratitic.

Measurements: See Table 1.

Disscussion: The "bottleneck" shaped venter and suture line are diagnostic of *Ambites*. Poor preservation makes identification at the species level difficult.

Family Mullericeratidae Ware, Jenks, Hautmann and Bucher, 2011

Genus *Mullericeras* Ware, Jenks, Hautmann and Bucher, 2011

Type species: *Aspidites spitiensis* Krafft in Krafft and Diener, 1909 from the *Meekoceras* bed of the Lower Triassic, Spiti, India.

Diagnosis: Smooth, very involute, compressed and tabulate platyconic to sub-oxyconic shells with a very broad ventral lobe bearing numerous small indentations but without adventitive series.

Mullericeras sp.

(Fig. 6A-G)

Material and occurrence: 7 specimens (NIGP 16332-16338) are registered. NIGP 16332-16336 are from Bed QB2-11 at the QB2 section. NIGP 16337-16338 are from float rocks at the QB2 section.

Description: Shell involute, sub-oxyconic at juvenile stage, more platyconic in later stages. Maximal thickness at the inner one-third of flanks. Venter bicarinate. At juvenile stage, umbilicus is narrow and deep, and umbilical wall is vertical to slightly overhanging. At larger size, the umbilicus tends to become wider and umbilical wall less vertical. Umbilical margin narrowly rounded, only a little higher than the adjecent part of flanks. Surface ornamented with very weak and distant folds, which are better visible at juvenile stage. Some faint folds can also be seen occasionally, forming bullae on the umbilical margin. Suture-line ceratitic.

Measurements: See Table 1.

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Discussion: Our specimens are close to those from Pakistan described by Ware et al. (in press). The only minor difference lies in the less convex flanks of the specimens from Qubu.

Genus *Ussuridiscus* Shigeta and Zakharov, 2009

Type species: *Meekoceras (kingites) varaha* Diener, 1895 from the Lower Triassic of Russia.

Diagnosis: Very involute, compressed tabulate shell. Suture line with a narrow ventral lobe bearing few small indentations.

Ussuridiscus? sp.

(Fig. 4E)

Material and occurrence: 1 specimen (NIGP 16339) is registered from Bed QB-18 at the QB section.

Description: Shell very involute, very compressed. Flanks slightly convex. Venter narrow. Umbilicus almost occluded. Suture line not very vell preserved but apparently ceratitic.

Measurements: See Table 1.

Disscussion: The poor preservation makes it difficult to assess the shape of the venter. Otherwise, the outline of the shell is in agreement with that of *Ussuridiscus*.

Family Proptychitidae Waagen, 1895

Genus *Proptychites* Waagen, 1895

Type species: *Ceratites lawrencianus* de Koninck, 1863 from the Lower Triassic of the Salt Range, Pakistan.

Diagnosis: Involute, moderately compressed to thick discoidal shell with a broadly rounded venter. Suture line complex, with deeply indented lobes.

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Proptychites cf. *pagi* Ware, Jenks, Hautmann and Bucher, 2011

(Fig. 5D)

?2011 *Proptychites pagi* – Ware et al., p. 175, text-fig. 18.

Material and occurrence: 1 specimen (NIGP 16340) is registered from a float block at the QB2 section.

Description: Shell moderately compressed. Flanks slightly convex with maximal thickness at the inner third of flanks. Venter broadly rounded. Umbilicus occluded. Surface smooth. Suture line unknown.

Measurements: See Table 1.

Discussion: Our specimen resembles very closely the type materials described by Ware et al. (2011) by its occuled umbilicus and whorl shape.

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Figure captions

Fig. 1. (a) Simplified Early Triassic palaeogography (modified from Péron et al., 2005; Brayard et al., 2006; Shigeta and Zakharov, 2009; Brühwiler et al., 2010) with the locations of Qubu (red spot), Spiti and the Salt Range (black spots). (b) Locations of Qubu, Tulong and Selong (red spots).
[1 column width]

Fig. 2. (a) QB section with lithologic units. (b) Synthetic stratigraphic log of the QB section with occurrences of ammonoids and conodonts. (c) Synthetic stratigraphic log of the QB2 section with occurrences of ammonoids.
[2 column width]

Fig. 3. (A, B) *Otoceras woodwardi* Griesbach, 1880; (A1-A3) NIGP 16320, lateral (right side) view (A1), ventral view (A2), apertural view (A3); (B1, B2) NIGP 16321, lateral (right side) view (B1), ventral view (B2); both from Bed QB-13. (C, D) *Ophiceras* sp.; (C1-C3) NIGP 16326, lateral (right side) view (C1), ventral view (C2), apertural view (C3); (D) NIGP 16327, lateral (right side) view; both from Bed QB-13. (E) *Ophiceras tibeticum* Griesbach, 1880, NIGP 16323, lateral (right side) view (E1), ventral view (E2), apertural view (E3), suture line (E4), from Bed QB-15.
[2 column width]

Fig. 4. (A, B) *Ophiceras tibeticum* Griesbach, 1880; (A1-A3) NIGP 16324, lateral (left side) view (A1), ventral view (A2), apertural view (A3), from Bed QB-16; (B1-B3) NIGP 16322, lateral (right side) view (B1), ventral view (B2), apertural view (B3), from Bed QB-15. (C) *Ophiceras demissum* Oppel, 1865, NIGP 16325, lateral (right side) view (C1), ventral view (C2), apertural view (C3), suture line (C4), from

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Bed QB-15. (D) *Discophiceras wordiei* Spath, 1930, NIGP 16328, lateral (left side) view (D1), ventral view (D2), apertural view (D3), suture line (D4), from Bed QB-15. (E) *Ussuridiscus*? sp., NIGP 16339, lateral (left side) view (E1), ventral view (E2), apertural view (E3), suture line (E4), from Bed QB-18.
[2 column width]

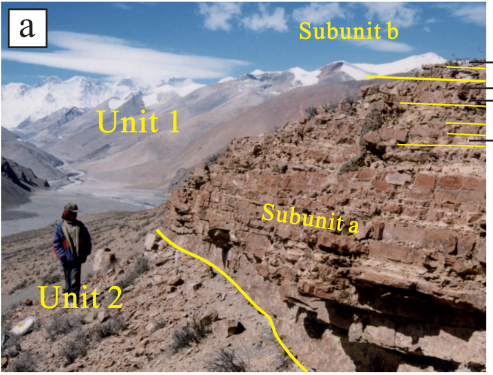
Fig. 5. (A-C) *Ambites* sp.; (A1-A5) NIGP 16329, lateral (right side) view (A1), lateral (left side) view (A2), ventral view (A3), apertural view (A4), suture line (A5), from Bed QB-18; (B1-B4) NIGP 16331, lateral (left side) view (B1), ventral view (B2), apertural view (B3), suture line (B4), from a float rock at the QB section; (C1-C3) NIGP 16330, lateral (left side) view (C1), apertural view (C2), suture line (C3), from Bed QB2-8. (D) *Proptychites* cf. *pagi* Ware, Jenks, Hautmann and Bucher, 2011, NIGP 16340, lateral (right side) view (D1), ventral view (D2), apertural view (D3), from a float rock at the QB2 section.
[2 column width]

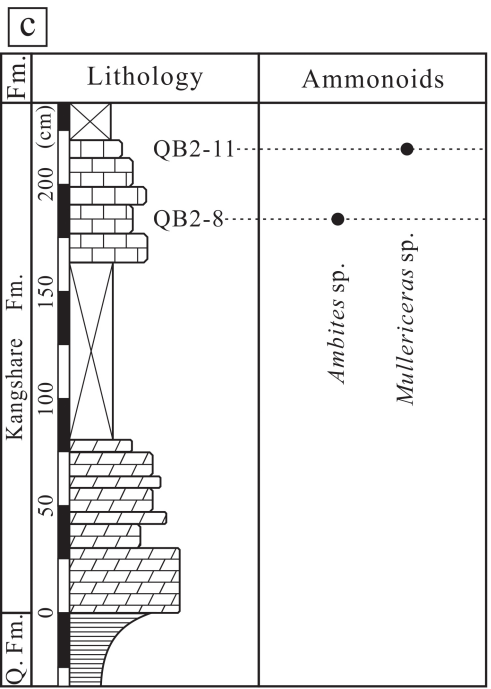
Fig. 6. (A-G) *Mullericeras* sp.; (A1-A3) NIGP 16332, lateral (right side) view (A1), ventral view (A2), apertural view (A3); (B1-B4) NIGP 16333, lateral (right side) view (B1), ventral view (B2), apertural view (B3), suture line (B4); (C1-C3) NIGP 16334, lateral (right side) view (C1), ventral view (C2), apertural view (C3); (D1-D4) NIGP 16335, lateral (right side) view (D1), ventral view (D2), apertural view (D3), suture line (D4); (E1-E3) NIGP 16336, lateral (right side) view (E1), ventral view (E2), apertural view (E3); (F1-F3) NIGP 16337, lateral (right side) view (F1), ventral view (F2), apertural view (F3); (G) NIGP 16338, lateral (right side) view. (A) and (D) are from float rocks at the QB2 section. All other specimens are from Bed QB2-11.
[2 column width]

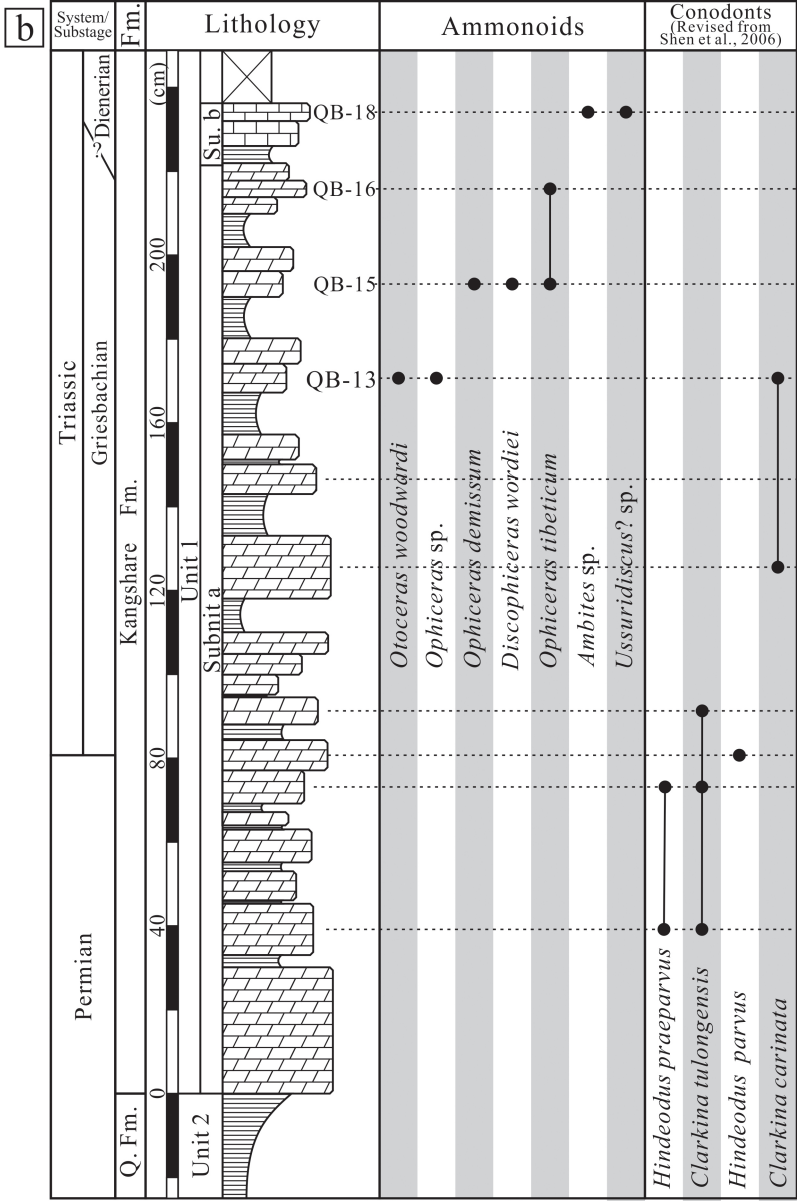
Fig. 7. Ammonoid biostratigraphic subdivisions of Qubu and correlation with zonations of other regions. PJRG: Pakistan-Japanese Research Group.
[1.5 column width]

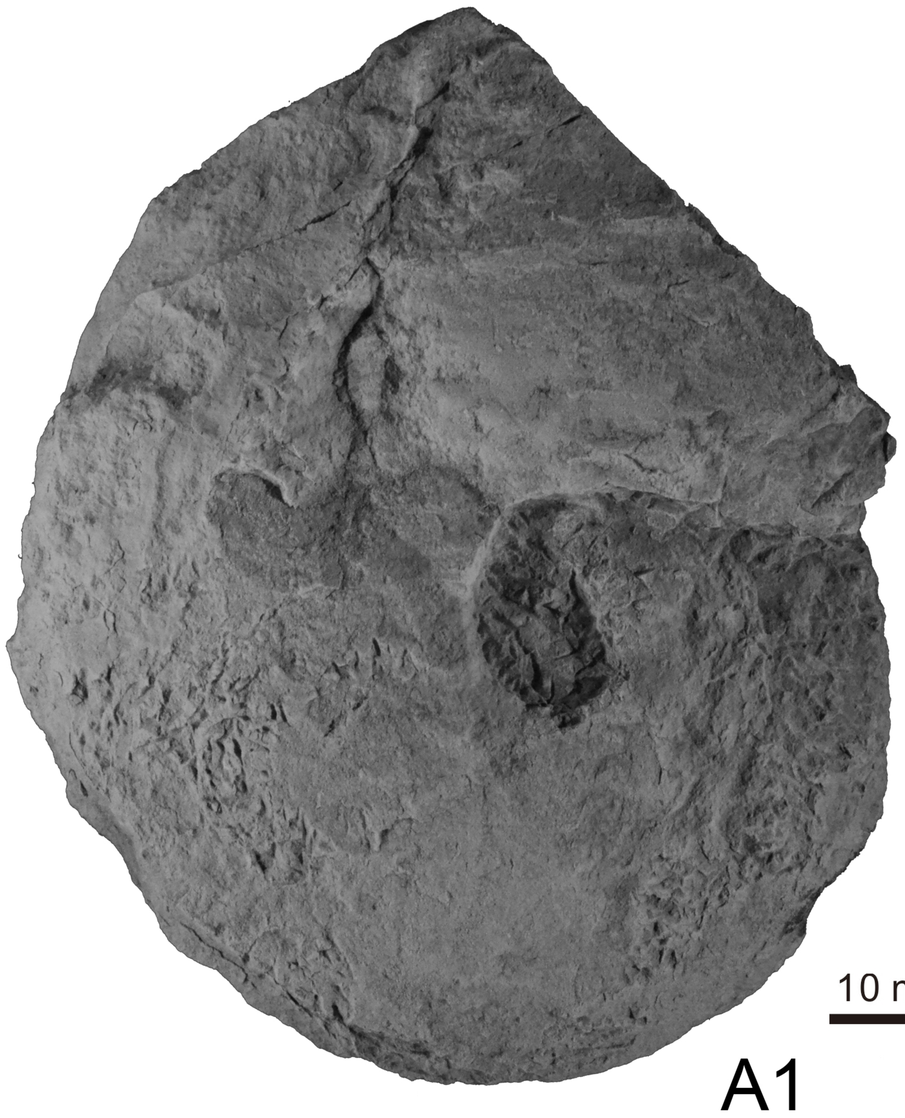
ACCEPTED MANUSCRIPT

a
60°N
30°N
0°
30°S
60°S
30°W
0°
30°E
60°E
90°E
120°E
150°E
Tethys
Salt Range
Spiti
Qubu
PANGEA
b
Borong
Menbu
Gangga
Tingri
Selong
Mt. Shishapangma
Yalai
Tulong
Zhaxizong
Qubu
Nyalam
China
Zhangmu
Mt. Everest
Nepal
2000 km
0
20
40 km


a
Subunit b
Unit 1
Subunit a
Unit 2
QB-18
QB-16
QB-15
QB-13


c
Fm.
Lithology
Ammonoids
(cm)
200
150
100
50
0
Kangshare Fm.
Q. Fm.
QB2-11
QB2-8
Ambites sp.
Mullericeras sp.
Su. b
Subunit b
Q. Fm.
Qubuerga Formation
Observed occurrence
Dolomitic limestone
Limestone
Shale


b
System/ Substage
Fm.
Lithology
Ammonoids
Conodonts
(Revised from Shen et al., 2006)
Triassic
Dienerian
Griesbachian
Permian
Kangshare Fm.
Q. Fm.
(cm)
200
160
120
80
40
0
Unit 1
Subunit a
Su. b
Unit 2
QB-18
QB-16
QB-15
QB-13
Otoceras woodwardi
Ophiceras sp.
Ophiceras demissum
Discophiceras wordiei
Ophiceras tibeticum
Ambites sp.
Ussuridiscus? sp.
Hindeodus praeparvus
Clarkina tulongensis
Hindeodus parvus
Clarkina carinata



10 mm

A1

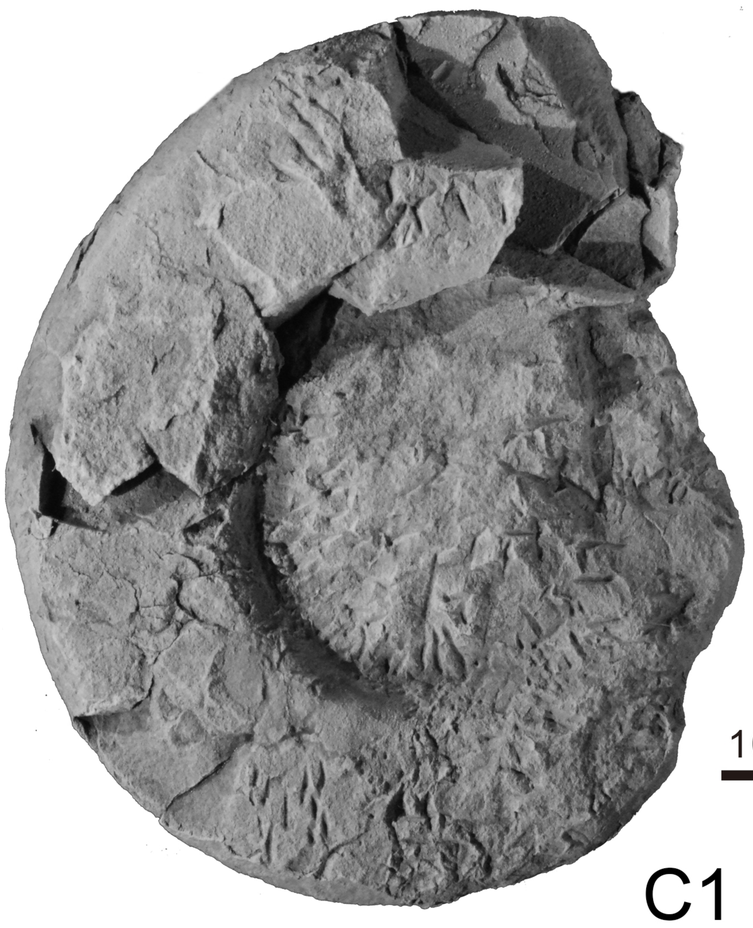
A2

A3

B1

10 mm

B2

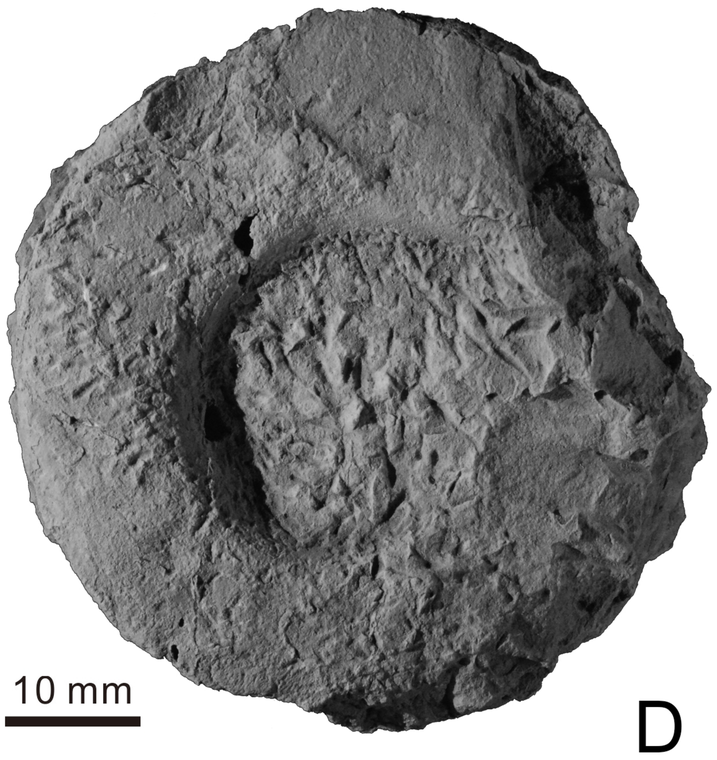


10 mm

C1

C2

C3



10 mm

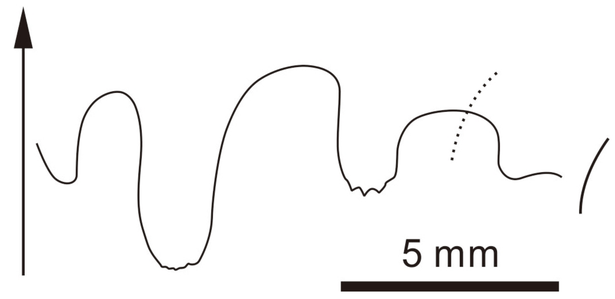
D

10 mm

E1

E2

E3



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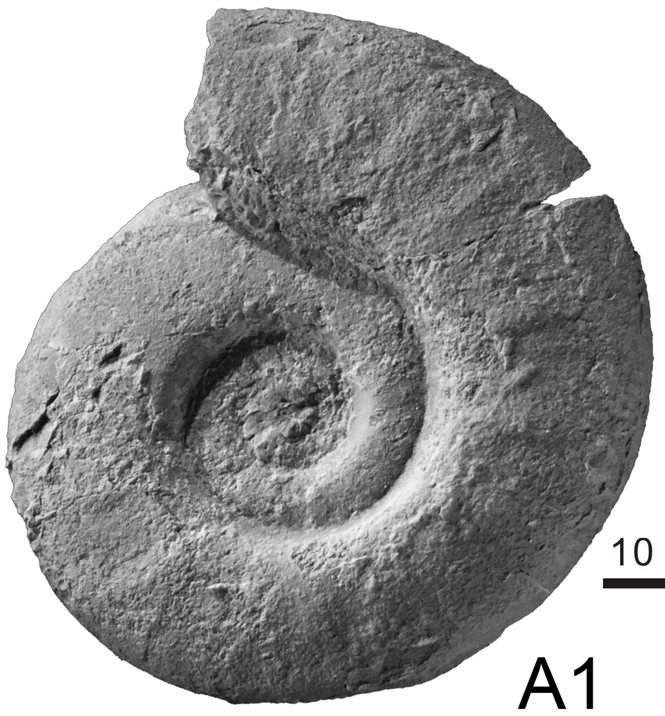
E4

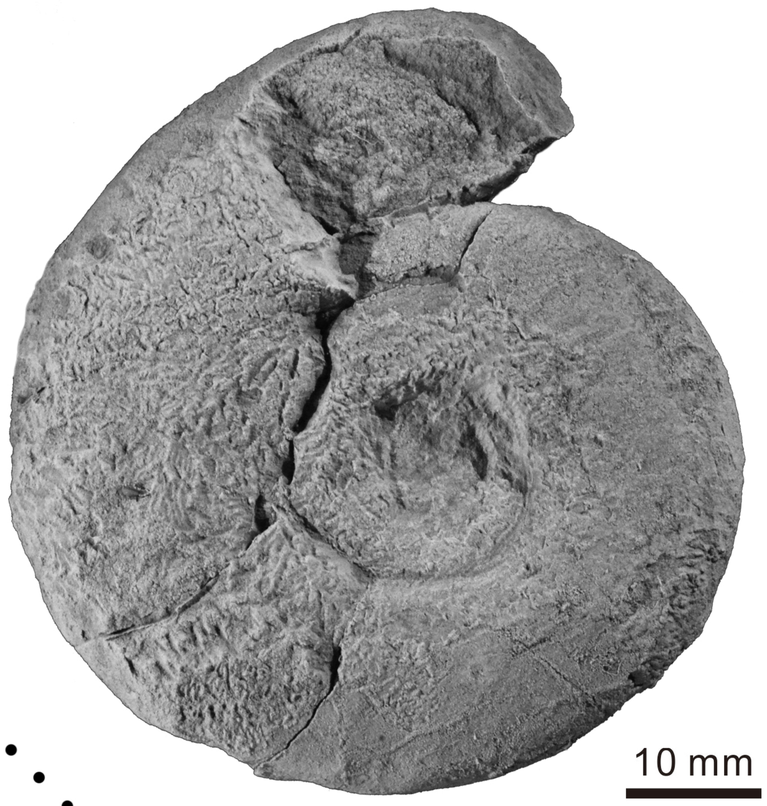


10 mm

A1

A2

A3

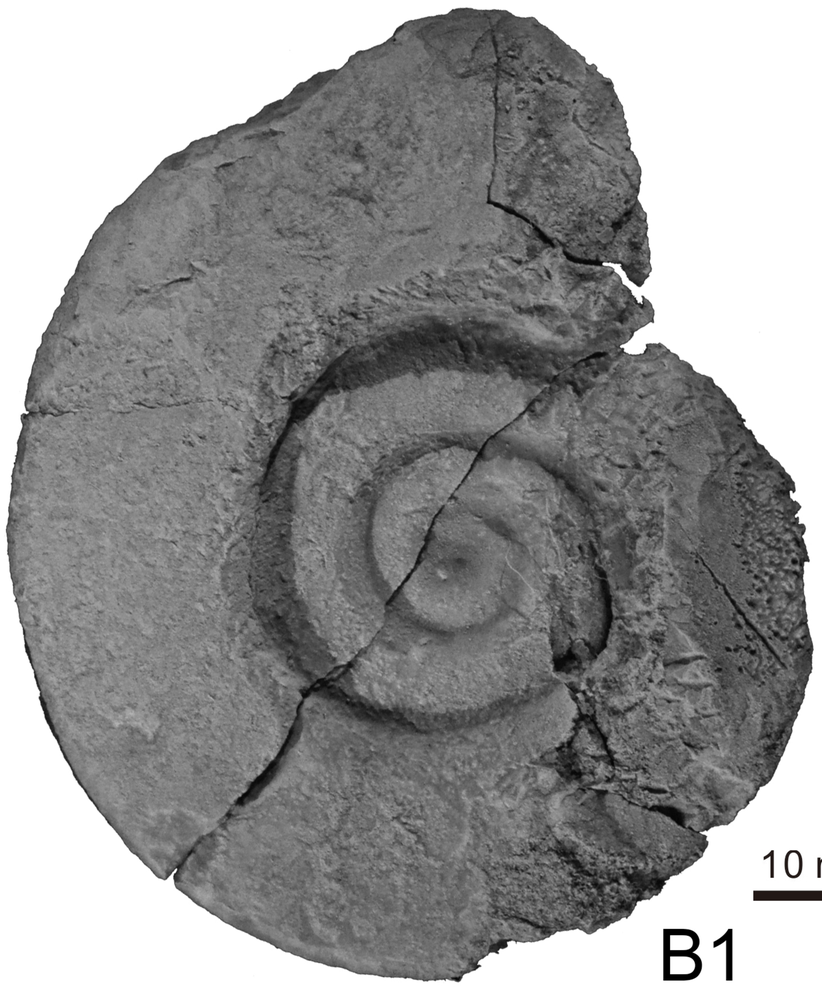


10 mm

C1

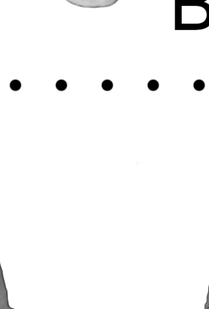
C2

C3



10 mm

B1



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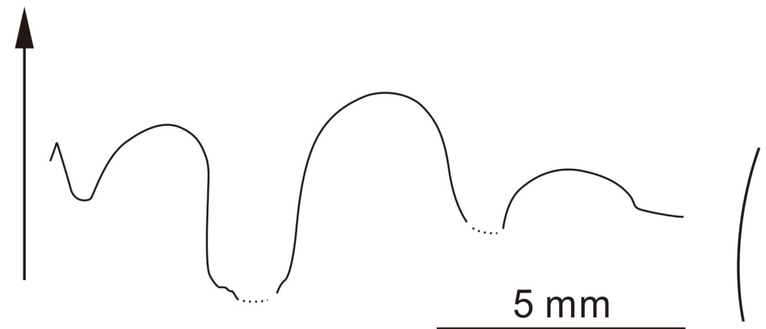
B3



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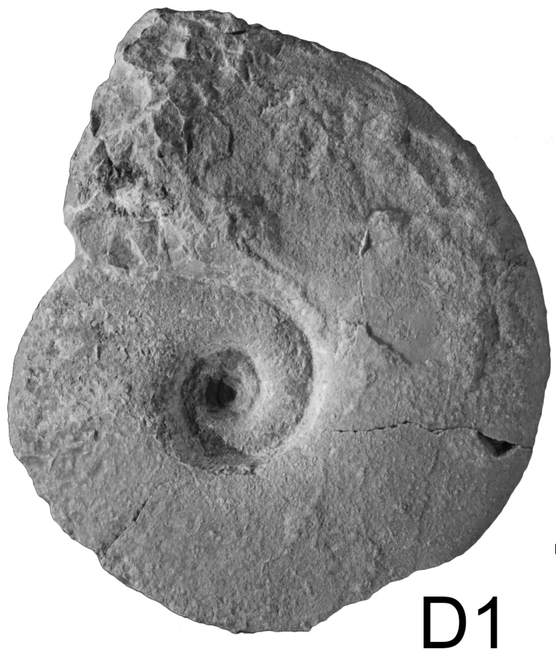


10 mm

D1

D2

D3

5 mm

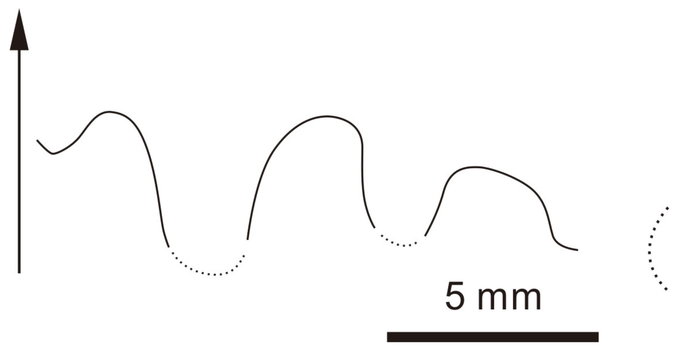
D4

10 mm

E1

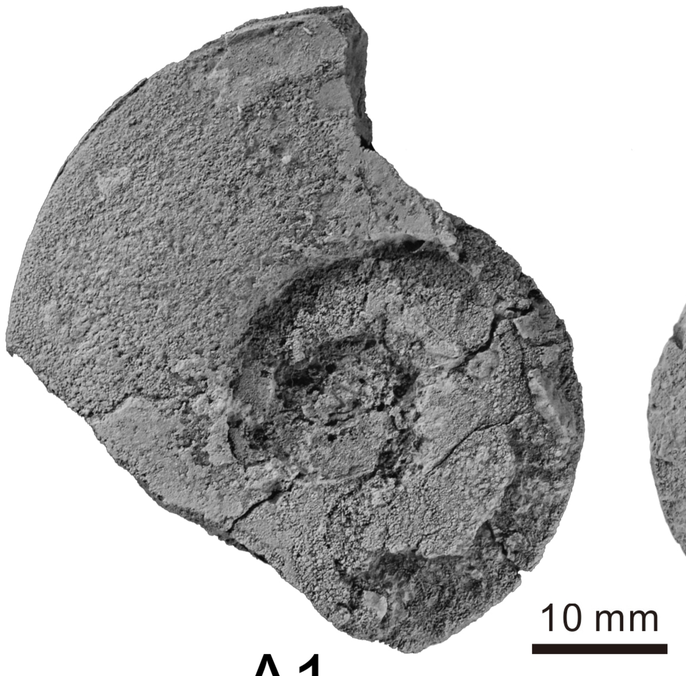
E2

E3



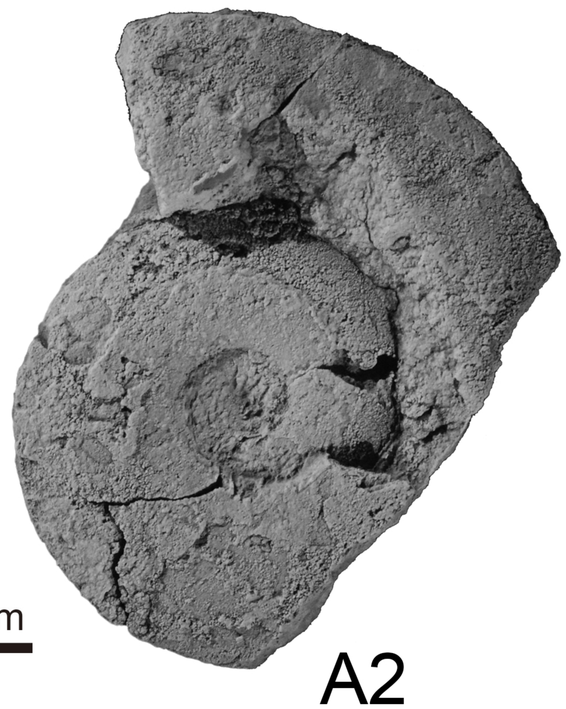
5 mm

E4



10 mm

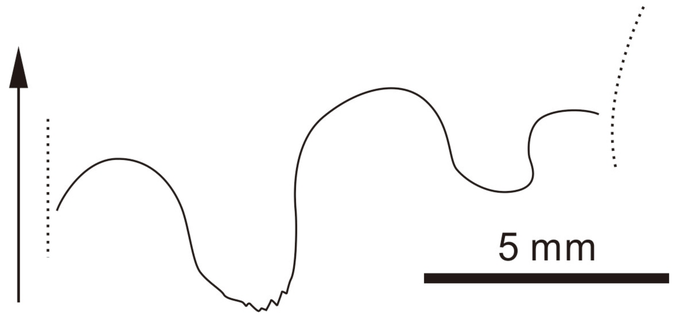
A1



A2

A3

A4



5 mm

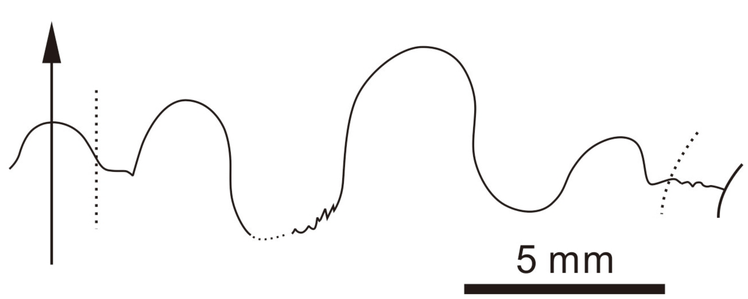
A5

B1

10 mm

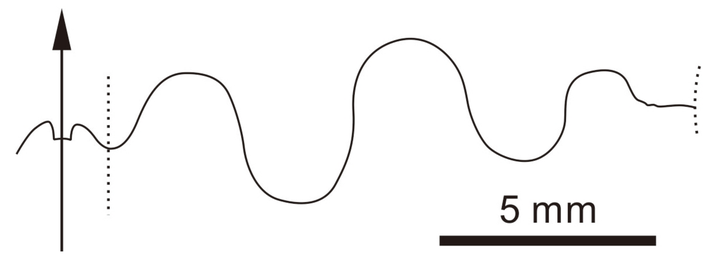
C1

C2



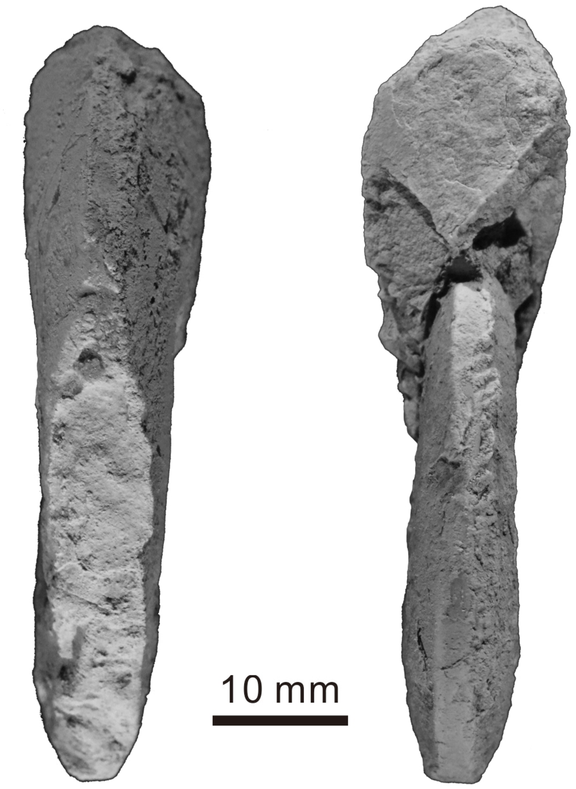
5 mm

B4



5 mm

C3



10 mm

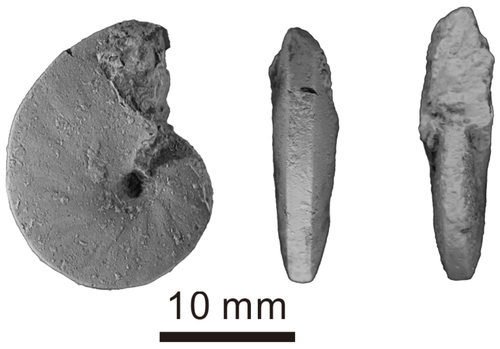
B2

B3

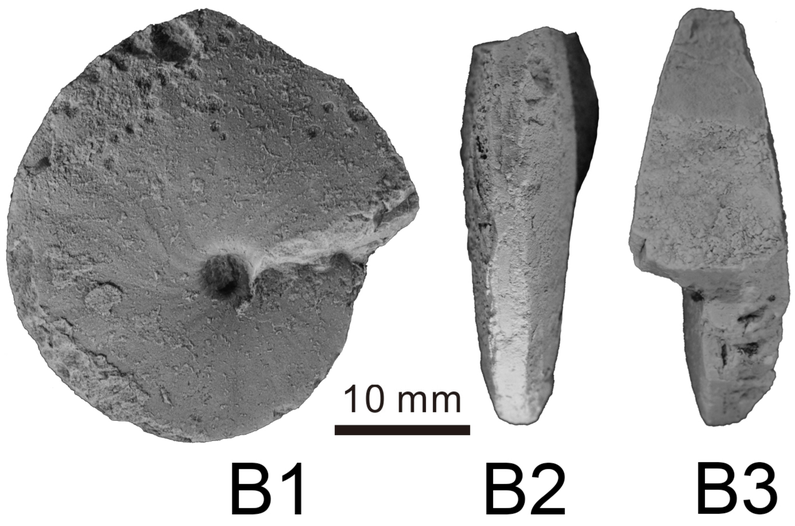
D1

D2

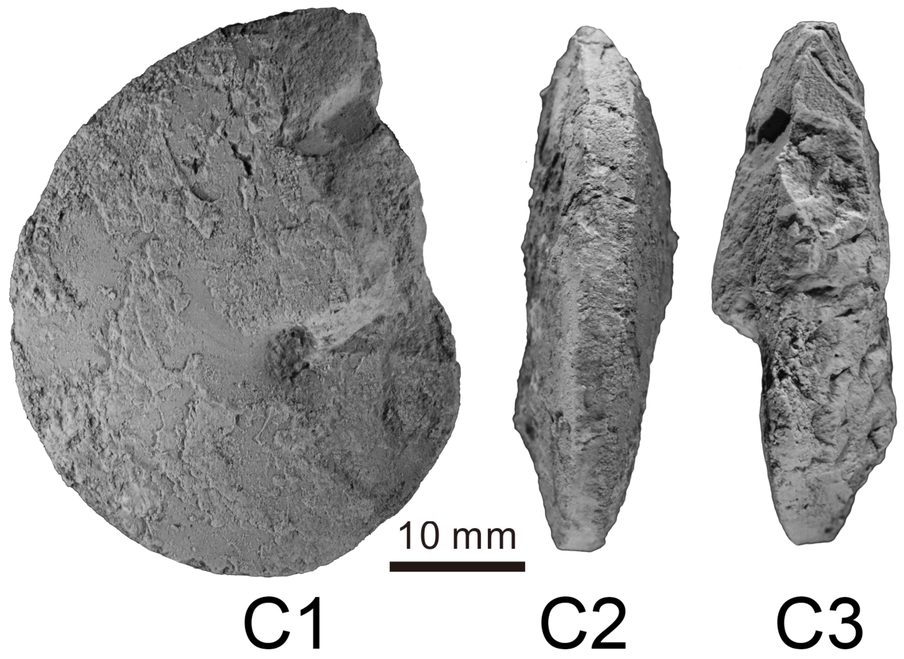
D3



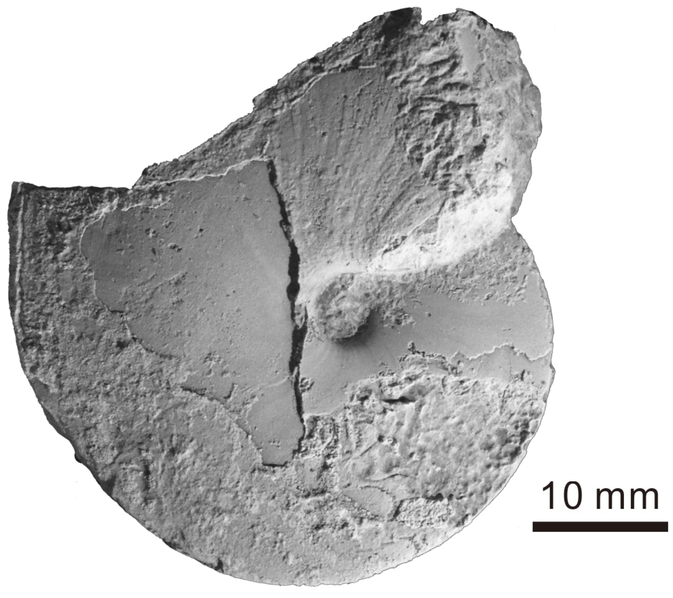
A1 A2 A3



B1 B2 B3



C1 C2 C3



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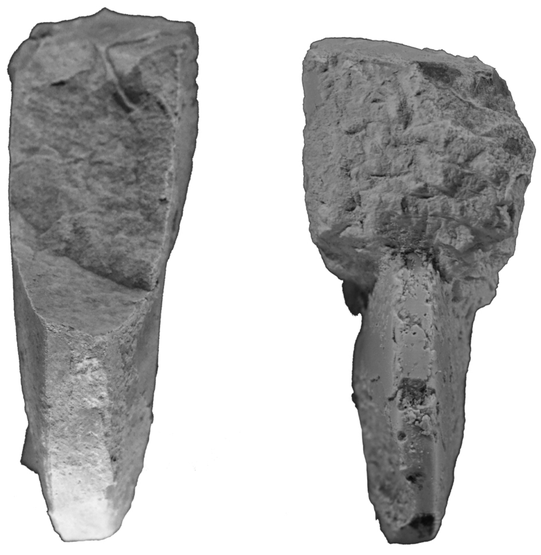
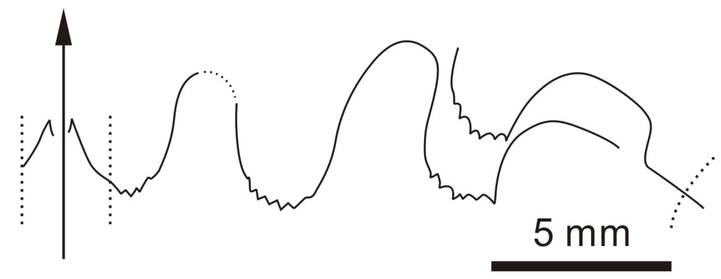


D2 D3



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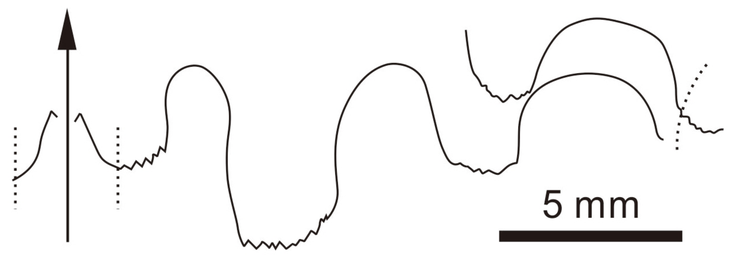

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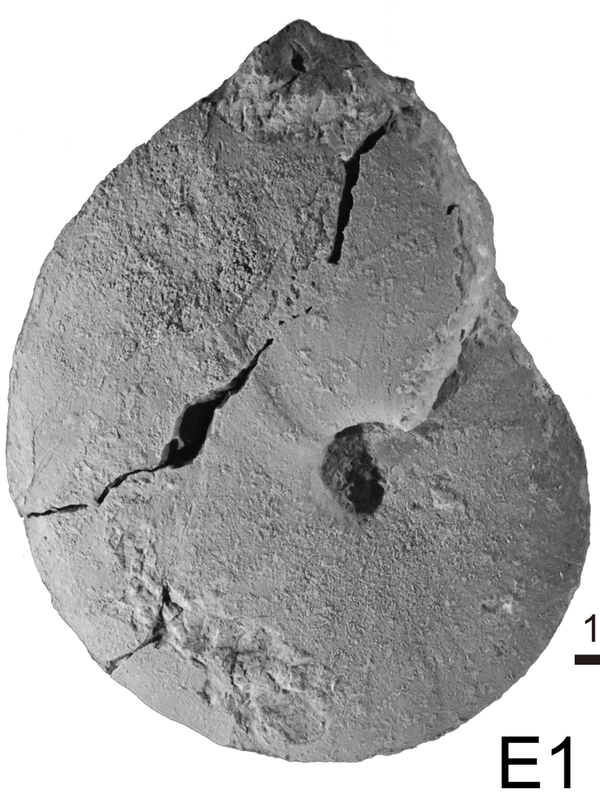
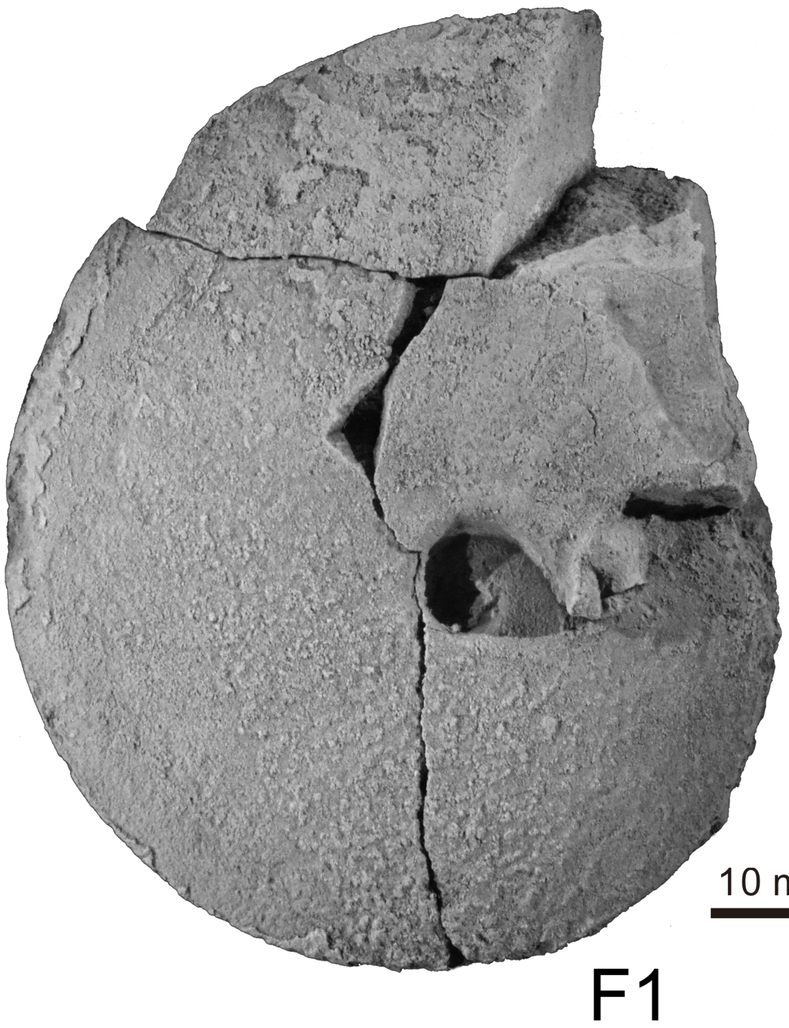


E1

E2

E3

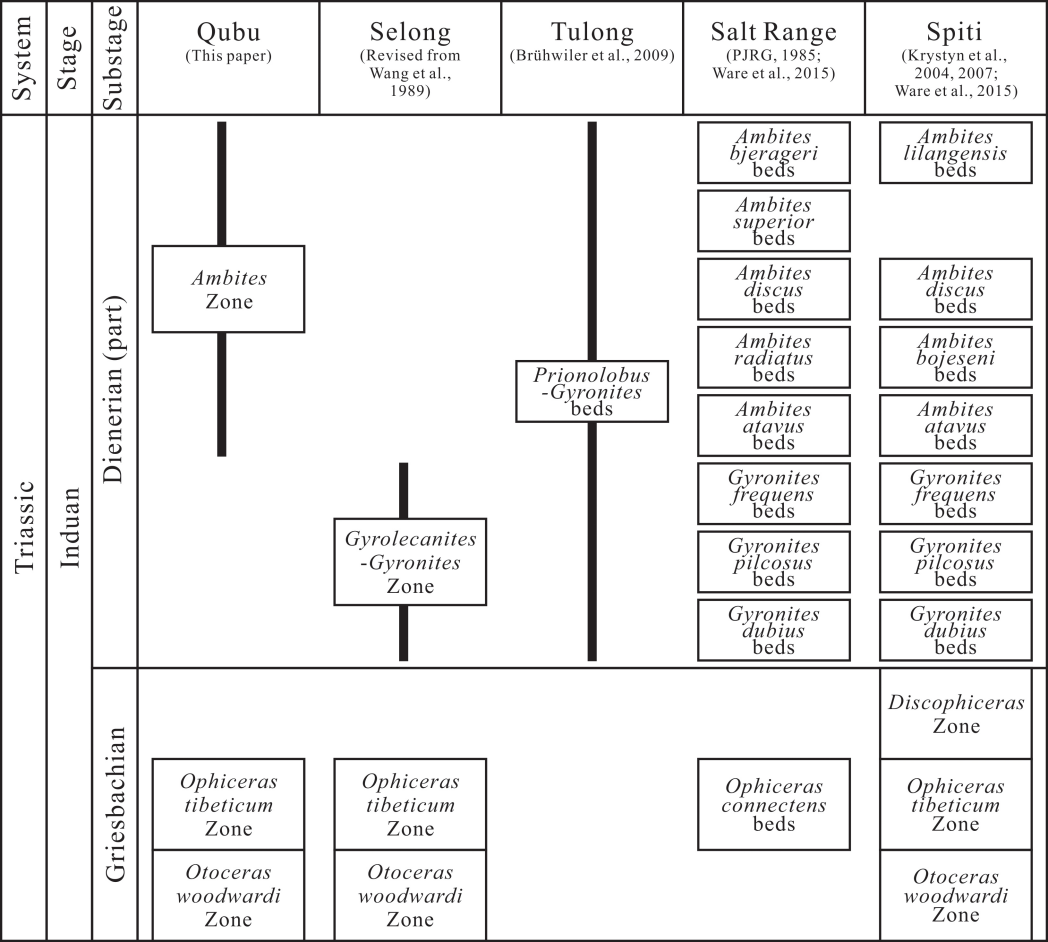


F1

F2

F3

G


System
Stage
Substage
Qubu
(This paper)
Selong
(Revised from Wang et al., 1989)
Tulong
(Brühwiler et al., 2009)
Salt Range
(PJRG, 1985; Ware et al., 2015)
Spiti
(Krystyn et al., 2004, 2007; Ware et al., 2015)
Triassic
Induan
Dienerian (part)
Griesbachian
Ambites Zone
Gyrolecanites -Gyronites Zone
Prionolobus -Gyronites beds
Ambites bjerageri beds
Ambites superior beds
Ambites discus beds
Ambites radiatus beds
Ambites atavus beds
Gyronites frequens beds
Gyronites pilcosus beds
Gyronites dubius beds
Ambites lilangensis beds
Ambites discus beds
Ambites bojeseni beds
Ambites atavus beds
Gyronites frequens beds
Gyronites pilcosus beds
Gyronites dubius beds
Discophiceras Zone
Ophiceras tibeticum Zone
Ophiceras connectens beds
Ophiceras tibeticum Zone
Otoceras woodwardi Zone
Otoceras woodwardi Zone
Otoceras woodwardi Zone